

Nano Focus

Electrostatic control achieved in block copolymers through morphology

The development of energy conversion and storage devices is at the forefront of research geared toward a sustainable future. However, materials limitations serve as bottlenecks in this progress. Typical liquid electrolytes used for the transport of ions between an anode and cathode are highly flammable and pose a safety hazard. Research efforts have focused on exploring solid electrolytes that do not have these limitations. Block copolymers are an alternative as solid electrolytes because they can self-assemble into nanostructures, which enables ion transport and maintains structural integrity. Furthermore, the ion conductivity can be controlled according to the nanostructure geometry.

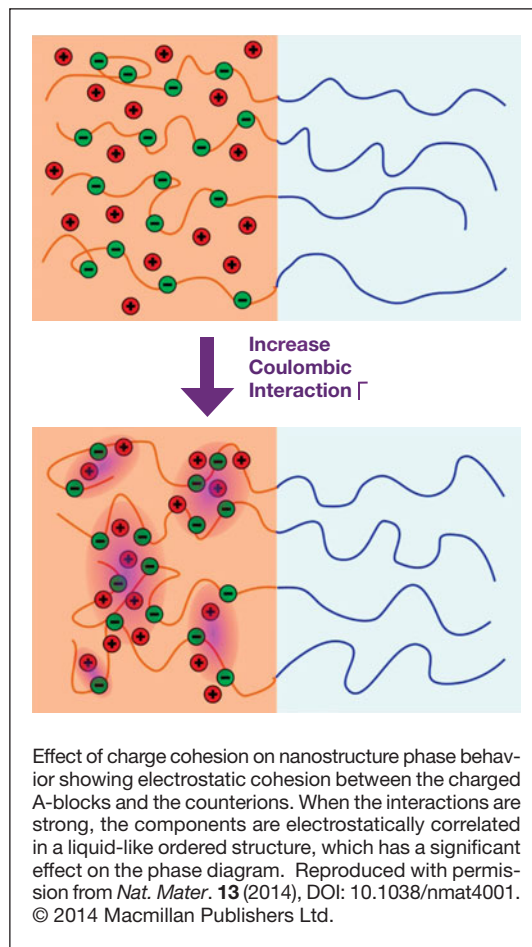
Researchers Charles E. Sing, Jos W. Zwanikken, and Monica Olivera de la Cruz from Northwestern University have used a theoretical model to demonstrate that the distribution of charge on the blocks comprising block copolymer systems can be used to manipulate the copolymer through inducement of an array of nanostructures. As reported in the July issue of *Nature Materials* (DOI: 10.1038/NMAT4001; p. 694), the

researchers varied the charge density along the block copolymer backbone through straightforward design of parameters. Charges along one of the blocks as well as the corresponding counterions dictate the equilibrium properties of the block copolymers through a combination of entropy, ion solubility, and electrostatic cohesion, which taken together drastically manipulate the phase behavior. The accompanying figure depicts the effect of charge cohesion on nanostructure phase behavior, demonstrating that highly asymmetric charge cohesion effects can induce the formation of nanostructures that are inaccessible to conventional uncharged block copolymers.

This work presents an orthogonal route toward tuning nanostructures that will have a significant impact on the design of block copolymer materials for use in numerous applications, such as in lithographic templates for small electronics, sensors, drug delivery, vehicle

filtration membranes, and materials with novel and tunable mechanical properties.

Jean L. Njoroge



Mechanical metamaterials produce ultralight, ultrastiff lattices

The word “metamaterial” conjures up visions of matter interacting with electromagnetic waves to bend the waves around objects, producing a “cloaking device” that hides the object from detection. But the “mechanical metamaterials” that Chris Spadaccini’s group at Lawrence Livermore National Laboratory and Nicholas Fang’s team at the Massachusetts Institute of Technology (MIT) are working on aim to avoid bending as much as possible—mechanical bending, that is. Instead, by causing forces to distribute only in stretching or compression modes

along the struts of an octet truss, they have fabricated ultralight, ultrastiff materials from polymers, metals, and ceramics. These materials could have applications in automobiles and aircraft, among other applications, where lightweighting could help conserve fuel without giving up strength.

“I don’t know who coined the term ‘mechanical metamaterial’ or ‘structural metamaterial,’” Spadaccini said, “but we think it’s appropriate in that a metamaterial is something that has a unique property that is based on the structure and the layout of the material as opposed to its composition.”

The unique properties of what Spadaccini calls their “architected”

material combine the lightness of an aerogel with a stiffness that is four orders of magnitude higher than that of a typical aerogel. The stiffness and density scale linearly over this range of magnitudes. In cellular materials found in nature, the scaling factor is usually a power of two (quadratic) or three (cubic) or higher, leading to deleterious nonlinear effects that result in a dramatic loss of stiffness with decreasing density. Natural materials tend to have more random pore sizes and distributions that lead to bending under stress.

“You really need to have more of those members within your material that are stretching or in compression as opposed to bending in order to move off that cubic relationship,” Spadaccini said. “But there